Full wwPDB X-ray Structure Validation Report ⓘ

Oct 7, 2026 – 12:09 PM JST

PDB ID	:	9VSH / pdb_00009vsh
Title	:	Crystal structure of the germacrene A synthase FpGAS-T169G mutant in complex with substrate FPP
Authors	:	Dong, S.; Zhang, H.
Deposited on	:	2025-07-08
Resolution	:	2.38 Å(reported)

This is a Full wwPDB X-ray Structure Validation Report for a publicly released PDB entry.

We welcome your comments at *validation@mail.wwpdb.org*
A user guide is available at
https://www.wwpdb.org/validation/2017/XrayValidationReportHelp
with specific help available everywhere you see the ⓘ symbol.

The types of validation reports are described at
http://www.wwpdb.org/validation/2017/FAQs#types.

The following versions of software and data (see references ⓘ) were used in the production of this report:

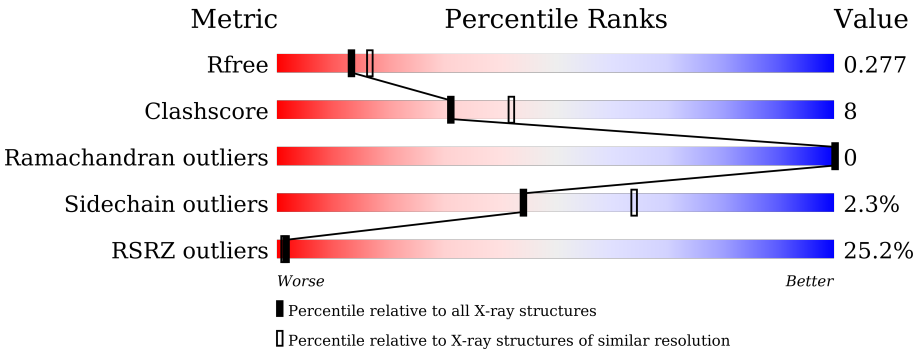
MolProbity	:	4-5-2 with Phenix2.2
Mogul	:	1.8.5 (274361), CSD as541be (2020)
Xtriage (Phenix)	:	2.2
EDS	:	3.0
Buster-report	:	wwPDB partial adaption of 1.1.7 (2018)
Percentile statistics	:	20250101.v01 (using entries in the PDB archive January 1st 2025)
CCP4	:	9.0.015 (Gargrove)
Density-Fitness	:	1.0.12
Ideal geometry (proteins)	:	Engh & Huber (2001)
Ideal geometry (DNA, RNA)	:	Parkinson et al. (1996)
Validation Pipeline (wwPDB-VP)	:	2.51

1 Overall quality at a glance (i)

The following experimental techniques were used to determine the structure:
X-RAY DIFFRACTION

The reported resolution of this entry is 2.38 Å.

Percentile scores (ranging between 0-100) for global validation metrics of the entry are shown in the following graphic. The table shows the number of entries on which the scores are based.



Metric	Whole archive (#Entries)	Similar resolution (#Entries, resolution range(Å))
R_{free}	180053	7164 (2.40-2.36)
Clashscore	190562	7722 (2.40-2.36)
Ramachandran outliers	187476	7626 (2.40-2.36)
Sidechain outliers	187428	7627 (2.40-2.36)
RSRZ outliers	180081	7170 (2.40-2.36)

The table below summarises the geometric issues observed across the polymeric chains and their fit to the electron density. The red, orange, yellow and green segments of the lower bar indicate the fraction of residues that contain outliers for >=3, 2, 1 and 0 types of geometric quality criteria respectively. A grey segment represents the fraction of residues that are not modelled. The numeric value for each fraction is indicated below the corresponding segment, with a dot representing fractions <=5% The upper red bar (where present) indicates the fraction of residues that have poor fit to the electron density. The numeric value is given above the bar.

Mol	Chain	Length	Quality of chain
1	A	313	25% 81% 18%

2 Entry composition (i)

There are 4 unique types of molecules in this entry. The entry contains 2632 atoms, of which 0 are hydrogens and 0 are deuteriums.

In the tables below, the ZeroOcc column contains the number of atoms modelled with zero occupancy, the AltConf column contains the number of residues with at least one atom in alternate conformation and the Trace column contains the number of residues modelled with at most 2 atoms.

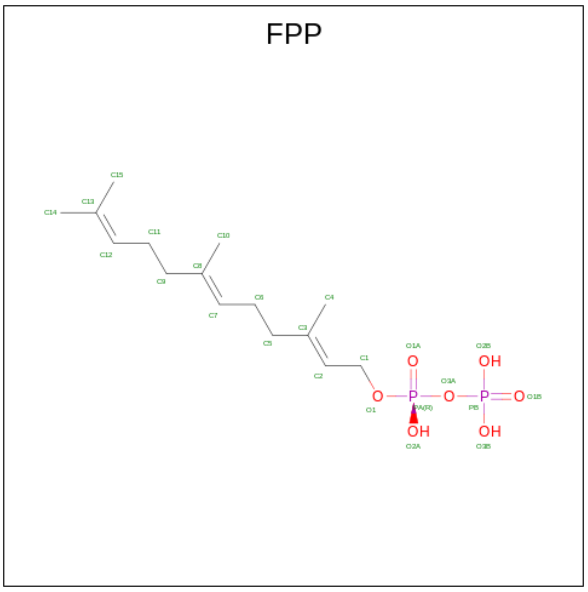
- Molecule 1 is a protein called Terpene synthase.

Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	Trace
			Total	C	N	O	S			
1	A	310	2498	1574	442	467	15	0	2	0

There are 9 discrepancies between the modelled and reference sequences:

Chain	Residue	Modelled	Actual	Comment	Reference
A	4	MET	-	initiating methionine	UNP A0A1B8B574
A	169	GLY	THR	engineered mutation	UNP A0A1B8B574
A	310	GLU	-	expression tag	UNP A0A1B8B574
A	311	HIS	-	expression tag	UNP A0A1B8B574
A	312	HIS	-	expression tag	UNP A0A1B8B574
A	313	HIS	-	expression tag	UNP A0A1B8B574
A	314	HIS	-	expression tag	UNP A0A1B8B574
A	315	HIS	-	expression tag	UNP A0A1B8B574
A	316	HIS	-	expression tag	UNP A0A1B8B574

- Molecule 2 is FARNESYL DIPHOSPHATE (CCD ID: FPP) (formula: $C_{15}H_{28}O_7P_2$) (labeled as "Ligand of Interest" by depositor).



Mol	Chain	Residues	Atoms	ZeroOcc	AltConf
2	A	1	Total C O P 24 15 7 2	0	0

- Molecule 3 is MAGNESIUM ION (CCD ID: MG) (formula: Mg) (labeled as "Ligand of Interest" by depositor).

Mol	Chain	Residues	Atoms	ZeroOcc	AltConf
3	A	3	Total Mg 3 3	0	0

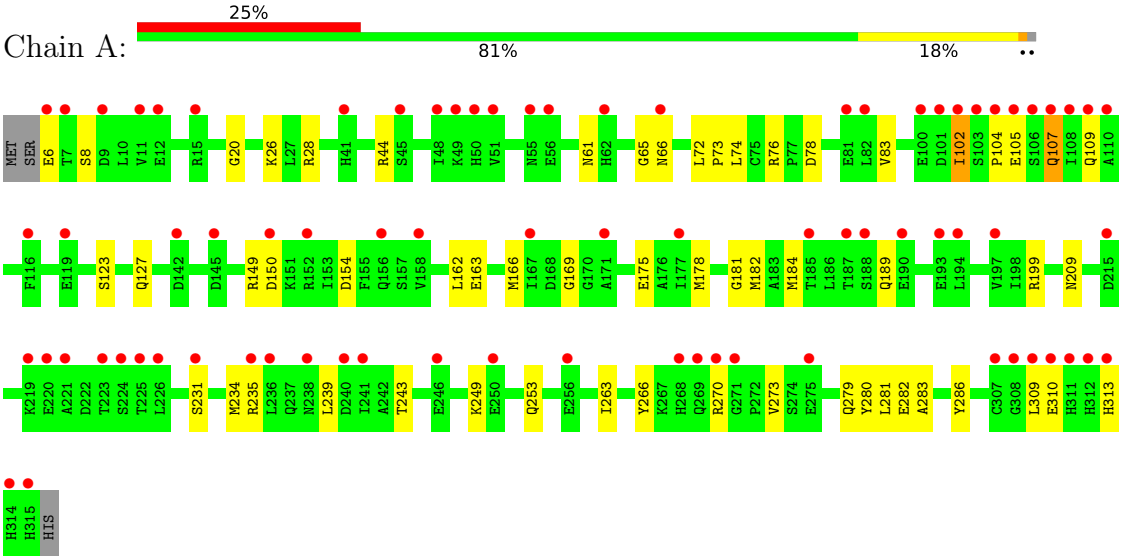
- Molecule 4 is water.

Mol	Chain	Residues	Atoms	ZeroOcc	AltConf
4	A	107	Total O 107 107	0	0

3 Residue-property plots (i)

These plots are drawn for all protein, RNA, DNA and oligosaccharide chains in the entry. The first graphic for a chain summarises the proportions of the various outlier classes displayed in the second graphic. The second graphic shows the sequence view annotated by issues in geometry and electron density. Residues are color-coded according to the number of geometric quality criteria for which they contain at least one outlier: green = 0, yellow = 1, orange = 2 and red = 3 or more. A red dot above a residue indicates a poor fit to the electron density (RSRZ > 2). Stretches of 2 or more consecutive residues without any outlier are shown as a green connector. Residues present in the sample, but not in the model, are shown in grey.

- Molecule 1: Terpene synthase



4 Data and refinement statistics (i)

Property	Value	Source
Space group	P 31 2 1	Depositor
Cell constants a, b, c, α, β, γ	136.28Å 136.28Å 55.05Å 90.00° 90.00° 120.00°	Depositor
Resolution (Å)	59.01 – 2.38 59.01 – 2.38	Depositor EDS
% Data completeness (in resolution range)	99.7 (59.01-2.38) 99.9 (59.01-2.38)	Depositor EDS
R_{merge}	0.26	Depositor
R_{sym}	(Not available)	Depositor
$< I/\sigma(I) >$ [1]	1.97 (at 2.37Å)	Xtriage
Refinement program	PHENIX (1.20.1_4487: ???)	Depositor
R, R_{free}	0.246 , 0.282 0.246 , 0.277	Depositor DCC
R_{free} test set	1153 reflections (4.84%)	wwPDB-VP
Wilson B-factor (Å^2)	36.5	Xtriage
Anisotropy	0.626	Xtriage
Bulk solvent k_{sol}(e/Å^3), B_{sol}(Å^2)	0.36 , 57.1	EDS
L-test for twinning[2]	$< \|L\| > = 0.49$, $< L^2 > = 0.33$	Xtriage
Estimated twinning fraction	0.063 for -h,-k,l	Xtriage
F_o,F_c correlation	0.89	EDS
Total number of atoms	2632	wwPDB-VP
Average B, all atoms (Å^2)	47.0	wwPDB-VP

Xtriage's analysis on translational NCS is as follows: *The largest off-origin peak in the Patterson function is 4.14% of the height of the origin peak. No significant pseudotranslation is detected.*

[1] Intensities estimated from amplitudes.

[2] Theoretical values of $< |L| >$, $< L^2 >$ for acentric reflections are 0.5, 0.333 respectively for untwinned datasets, and 0.375, 0.2 for perfectly twinned datasets.

5 Model quality

5.1 Standard geometry

Bond lengths and bond angles in the following residue types are not validated in this section: FPP, MG

The Z score for a bond length (or angle) is the number of standard deviations the observed value is removed from the expected value. A bond length (or angle) with $|Z| > 5$ is considered an outlier worth inspection. RMSZ is the root-mean-square of all Z scores of the bond lengths (or angles).

Mol	Chain	Bond lengths		Bond angles	
		RMSZ	$\#\|Z\| > 5$	RMSZ	$\#\|Z\| > 5$
1	A	0.20	0/2557	0.35	0/3455

There are no bond length outliers.

There are no bond angle outliers.

There are no chirality outliers.

There are no planarity outliers.

5.2 Too-close contacts

In the following table, the Non-H and H(model) columns list the number of non-hydrogen atoms and hydrogen atoms in the chain respectively. The H(added) column lists the number of hydrogen atoms added and optimized by MolProbity. The Clashes column lists the number of clashes within the asymmetric unit, whereas Symm-Clashes lists symmetry-related clashes.

Mol	Chain	Non-H	H(model)	H(added)	Clashes	Symm-Clashes
1	A	2498	0	2429	36	0
2	A	24	0	25	8	0
3	A	3	0	0	0	0
4	A	107	0	0	5	0
All	All	2632	0	2454	41	0

The all-atom clashscore is defined as the number of clashes found per 1000 atoms (including hydrogen atoms). The all-atom clashscore for this structure is 8.

All (41) close contacts within the same asymmetric unit are listed below, sorted by their clash magnitude.

Atom-1	Atom-2	Interatomic distance (Å)	Clash overlap (Å)
1:A:231:SER:HA	1:A:234:MET:HE2	1.64	0.78
2:A:401:FPP:H143	4:A:505:HOH:O	1.84	0.76
1:A:104:PRO:HA	1:A:107:GLN:HB3	1.72	0.70
1:A:169:GLY:HA2	2:A:401:FPP:H12A	1.77	0.67
1:A:72:LEU:HD22	1:A:178:MET:HB2	1.81	0.63
1:A:102:ILE:O	1:A:102:ILE:HD13	2.00	0.61
1:A:6:GLU:N	4:A:512:HOH:O	2.35	0.60
1:A:163:GLU:OE2	1:A:199:ARG:NH2	2.34	0.57
2:A:401:FPP:H2	2:A:401:FPP:C7	2.33	0.57
1:A:263:ILE:HG12	1:A:281:LEU:HD12	1.86	0.57
2:A:401:FPP:C7	2:A:401:FPP:C2	2.85	0.55
1:A:280:TYR:HD1	1:A:281:LEU:HD22	1.72	0.55
1:A:169:GLY:O	2:A:401:FPP:H42	2.07	0.54
2:A:401:FPP:C1	4:A:505:HOH:O	2.57	0.52
1:A:107:GLN:C	1:A:109:GLN:N	2.68	0.51
1:A:209:ASN:ND2	2:A:401:FPP:H52	2.26	0.50
1:A:66:ASN:OD1	4:A:501:HOH:O	2.20	0.49
1:A:162:LEU:O	1:A:166:MET:HG3	2.13	0.49
1:A:20:GLY:O	1:A:253:GLN:NE2	2.47	0.48
1:A:239:LEU:HD13	1:A:243:THR:HG22	1.95	0.48
1:A:44:ARG:HE	1:A:309:LEU:HD21	1.79	0.47
1:A:154:ASP:OD1	1:A:235:ARG:NH1	2.49	0.46
1:A:76:ARG:HG3	1:A:181:GLY:O	2.16	0.46
1:A:175:GLU:OE2	1:A:280:TYR:OH	2.27	0.46
1:A:123:SER:O	1:A:127:GLN:HG2	2.16	0.45
1:A:149:ARG:NH2	1:A:150:ASP:OD2	2.49	0.45
1:A:8:SER:OG	1:A:28:ARG:HD3	2.17	0.45
1:A:74:LEU:HD21	1:A:286:TYR:CD2	2.52	0.44
1:A:266:TYR:CE1	1:A:270:ARG:HG3	2.52	0.44
1:A:78:ASP:OD1	1:A:78:ASP:N	2.46	0.43
1:A:184:MET:HE1	1:A:279:GLN:HG2	2.00	0.43
1:A:74:LEU:HD21	1:A:286:TYR:HD2	1.83	0.42
1:A:73:PRO:HG2	1:A:74:LEU:HD22	2.01	0.42
2:A:401:FPP:H111	2:A:401:FPP:H101	1.54	0.42
1:A:26:LYS:HB2	1:A:26:LYS:HE3	1.64	0.42
1:A:313:HIS:HA	4:A:535:HOH:O	2.19	0.41
1:A:182:MET:HE1	1:A:283:ALA:HB2	2.03	0.40
1:A:26:LYS:NZ	1:A:282:GLU:OE1	2.50	0.40
1:A:249:LYS:HB2	1:A:249:LYS:HE3	1.68	0.40
1:A:189:GLN:CD	1:A:189:GLN:H	2.30	0.40
1:A:61:ASN:HB3	1:A:65:GLY:O	2.22	0.40

There are no symmetry-related clashes.

5.3 Torsion angles (i)

5.3.1 Protein backbone (i)

In the following table, the Percentiles column shows the percent Ramachandran outliers of the chain as a percentile score with respect to all X-ray entries followed by that with respect to entries of similar resolution.

The Analysed column shows the number of residues for which the backbone conformation was analysed, and the total number of residues.

Mol	Chain	Analysed	Favoured	Allowed	Outliers	Percentiles
1	A	310/313 (99%)	301 (97%)	9 (3%)	0	100 100

There are no Ramachandran outliers to report.

5.3.2 Protein sidechains (i)

In the following table, the Percentiles column shows the percent sidechain outliers of the chain as a percentile score with respect to all X-ray entries followed by that with respect to entries of similar resolution.

The Analysed column shows the number of residues for which the sidechain conformation was analysed, and the total number of residues.

Mol	Chain	Analysed	Rotameric	Outliers	Percentiles
1	A	267/271 (98%)	261 (98%)	6 (2%)	45 65

All (6) residues with a non-rotameric sidechain are listed below:

Mol	Chain	Res	Type
1	A	83	VAL
1	A	102	ILE
1	A	105	GLU
1	A	107	GLN
1	A	273	VAL
1	A	310	GLU

Sometimes sidechains can be flipped to improve hydrogen bonding and reduce clashes. All (8) such sidechains are listed below:

Mol	Chain	Res	Type
1	A	41	HIS
1	A	107	GLN

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Mol	Chain	Res	Type
1	A	127	GLN
1	A	156	GLN
1	A	189	GLN
1	A	278	HIS
1	A	287	GLN
1	A	313	HIS

5.3.3 RNA

There are no RNA molecules in this entry.

5.4 Non-standard residues in protein, DNA, RNA chains

There are no non-standard protein/DNA/RNA residues in this entry.

5.5 Carbohydrates

There are no oligosaccharides in this entry.

5.6 Ligand geometry

Of 4 ligands modelled in this entry, 3 are monoatomic - leaving 1 for Mogul analysis.

In the following table, the Counts columns list the number of bonds (or angles) for which Mogul statistics could be retrieved, the number of bonds (or angles) that are observed in the model and the number of bonds (or angles) that are defined in the Chemical Component Dictionary. The Link column lists molecule types, if any, to which the group is linked. The Z score for a bond length (or angle) is the number of standard deviations the observed value is removed from the expected value. A bond length (or angle) with $|Z| > 2$ is considered an outlier worth inspection. RMSZ is the root-mean-square of all Z scores of the bond lengths (or angles).

Mol	Type	Chain	Res	Link	Bond lengths			Bond angles		
					Counts	RMSZ	$\#\|Z\| > 2$	Counts	RMSZ	$\#\|Z\| > 2$
2	FPP	A	401	3	21,23,23	1.40	5 (23%)	27,31,31	1.94	7 (25%)

In the following table, the Chirals column lists the number of chiral outliers, the number of chiral centers analysed, the number of these observed in the model and the number defined in the Chemical Component Dictionary. Similar counts are reported in the Torsion and Rings columns. '-' means no outliers of that kind were identified.

Mol	Type	Chain	Res	Link	Chirals	Torsions	Rings
2	FPP	A	401	3	-	8/25/25/25	-

All (5) bond length outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(Å)	Ideal(Å)
2	A	401	FPP	PB-O2B	-3.94	1.39	1.54
2	A	401	FPP	PB-O3B	-2.74	1.44	1.54
2	A	401	FPP	PA-O2A	-2.29	1.44	1.55
2	A	401	FPP	PA-O1	-2.10	1.50	1.59
2	A	401	FPP	PA-O1A	-2.04	1.43	1.50

All (7) bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(^{o})	Ideal(^{o})
2	A	401	FPP	C1-C2-C3	4.69	134.16	126.04
2	A	401	FPP	C6-C7-C8	-3.88	118.31	127.66
2	A	401	FPP	C10-C8-C9	3.62	121.36	115.27
2	A	401	FPP	C5-C3-C2	-2.58	115.90	121.12
2	A	401	FPP	PA-O3A-PB	-2.55	124.07	132.83
2	A	401	FPP	C11-C12-C13	-2.42	119.46	127.75
2	A	401	FPP	O2B-PB-O1B	2.14	119.07	110.68

There are no chirality outliers.

All (8) torsion outliers are listed below:

Mol	Chain	Res	Type	Atoms
2	A	401	FPP	C2-C1-O1-PA
2	A	401	FPP	C1-O1-PA-O1A
2	A	401	FPP	C1-O1-PA-O2A
2	A	401	FPP	C1-O1-PA-O3A
2	A	401	FPP	C7-C8-C9-C11
2	A	401	FPP	C10-C8-C9-C11
2	A	401	FPP	C12-C11-C9-C8
2	A	401	FPP	C4-C3-C5-C6

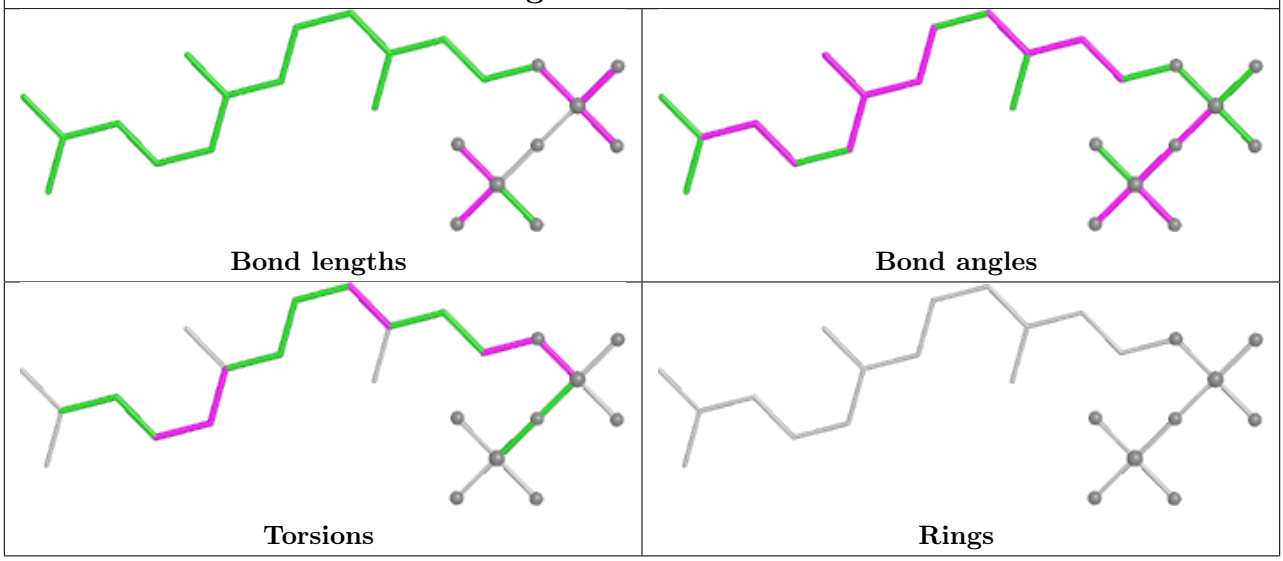
There are no ring outliers.

1 monomer is involved in 8 short contacts:

Mol	Chain	Res	Type	Clashes	Symm-Clashes
2	A	401	FPP	8	0

The following is a two-dimensional graphical depiction of Mogul quality analysis of bond lengths, bond angles, torsion angles, and ring geometry for all instances of the Ligand of Interest. In addition, ligands with molecular weight > 250 and outliers as shown on the validation Tables will also be included. For torsion angles, if less then 5% of the Mogul distribution of torsion angles is within 10 degrees of the torsion angle in question, then that torsion angle is considered an outlier. Any bond that is central to one or more torsion angles identified as an outlier by Mogul will be highlighted in the graph. For rings, the root-mean-square deviation (RMSD) between the ring in question and similar rings identified by Mogul is calculated over all ring torsion angles. If the average RMSD is greater than 60 degrees and the minimal RMSD between the ring in question and any Mogul-identified rings is also greater than 60 degrees, then that ring is considered an outlier. The outliers are highlighted in purple. The color gray indicates Mogul did not find sufficient equivalents in the CSD to analyse the geometry.

Ligand FPP A 401



5.7 Other polymers (i)

There are no such residues in this entry.

5.8 Polymer linkage issues (i)

There are no chain breaks in this entry.

6 Fit of model and data

6.1 Protein, DNA and RNA chains

In the following table, the column labelled '#RSRZ> 2' contains the number (and percentage) of RSRZ outliers, followed by percent RSRZ outliers for the chain as percentile scores relative to all X-ray entries and entries of similar resolution. The OWAB column contains the minimum, median, 95th percentile and maximum values of the occupancy-weighted average B-factor per residue. The column labelled 'Q< 0.9' lists the number of (and percentage) of residues with an average occupancy less than 0.9.

Mol	Chain	Analysed	<RSRZ>	#RSRZ>2	OWAB(Å^2)	Q<0.9
1	A	310/313 (99%)	1.55	78 (25%) 1 1	26, 45, 71, 102	2 (0%)

All (78) RSRZ outliers are listed below:

Mol	Chain	Res	Type	RSRZ
1	A	313	HIS	7.2
1	A	102	ILE	5.8
1	A	108	ILE	5.7
1	A	309	LEU	4.9
1	A	104	PRO	4.9
1	A	311	HIS	4.6
1	A	103	SER	4.6
1	A	106	SER	4.5
1	A	100	GLU	4.3
1	A	62[A]	HIS	4.2
1	A	269	GLN	4.0
1	A	101	ASP	4.0
1	A	150	ASP	4.0
1	A	220	GLU	3.9
1	A	308	GLY	3.9
1	A	6	GLU	3.8
1	A	105	GLU	3.8
1	A	236	LEU	3.7
1	A	11	VAL	3.6
1	A	312	HIS	3.5
1	A	109	GLN	3.4
1	A	310	GLU	3.4
1	A	271	GLY	3.4
1	A	56	GLU	3.2
1	A	107	GLN	3.2
1	A	250	GLU	3.1
1	A	215	ASP	3.1

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Mol	Chain	Res	Type	RSRZ
1	A	223	THR	3.0
1	A	270	ARG	3.0
1	A	307	CYS	3.0
1	A	7	THR	3.0
1	A	246	GLU	3.0
1	A	314	HIS	2.9
1	A	315	HIS	2.9
1	A	224	SER	2.9
1	A	256	GLU	2.9
1	A	41	HIS	2.8
1	A	55	ASN	2.7
1	A	81	GLU	2.7
1	A	241	ILE	2.7
1	A	231	SER	2.7
1	A	197	VAL	2.7
1	A	45	SER	2.7
1	A	194	LEU	2.7
1	A	110	ALA	2.6
1	A	142	ASP	2.6
1	A	158	VAL	2.6
1	A	48	ILE	2.6
1	A	219	LYS	2.5
1	A	275	GLU	2.5
1	A	268	HIS	2.5
1	A	12	GLU	2.4
1	A	190	GLU	2.4
1	A	226	LEU	2.4
1	A	167	ILE	2.4
1	A	9	ASP	2.4
1	A	66	ASN	2.4
1	A	187	THR	2.4
1	A	177	ILE	2.4
1	A	156	GLN	2.4
1	A	235	ARG	2.3
1	A	152	ARG	2.3
1	A	221	ALA	2.3
1	A	15	ARG	2.2
1	A	193	GLU	2.2
1	A	185	THR	2.2
1	A	51	VAL	2.2
1	A	145	ASP	2.2
1	A	188	SER	2.2

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Mol	Chain	Res	Type	RSRZ
1	A	49	LYS	2.1
1	A	240	ASP	2.1
1	A	225	THR	2.1
1	A	171	ALA	2.1
1	A	119	GLU	2.1
1	A	116	PHE	2.1
1	A	238	ASN	2.0
1	A	50	HIS	2.0
1	A	82	LEU	2.0

6.2 Non-standard residues in protein, DNA, RNA chains (i)

There are no non-standard protein/DNA/RNA residues in this entry.

6.3 Carbohydrates (i)

There are no oligosaccharides in this entry.

6.4 Ligands (i)

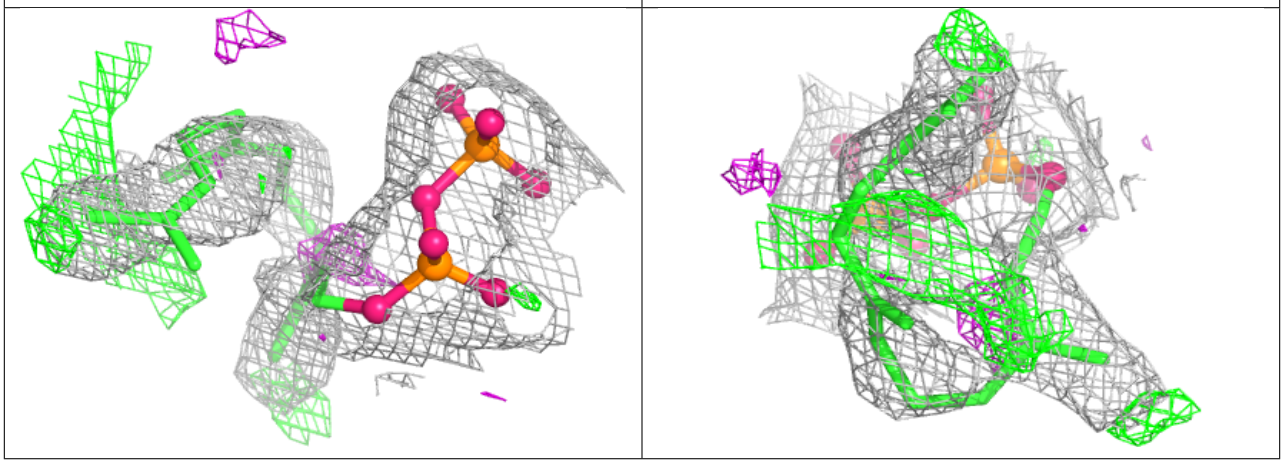
In the following table, the Atoms column lists the number of modelled atoms in the group and the number defined in the chemical component dictionary. The B-factors column lists the minimum, median, 95th percentile and maximum values of B factors of atoms in the group. The column labelled 'Q< 0.9' lists the number of atoms with occupancy less than 0.9.

Mol	Type	Chain	Res	Atoms	RSCC	RSR	B-factors(Å^2)	Q<0.9
2	FPP	A	401	24/24	0.93	0.17	27,44,62,67	0
3	MG	A	402	1/1	0.94	0.06	30,30,30,30	0
3	MG	A	404	1/1	0.94	0.07	28,28,28,28	0
3	MG	A	403	1/1	0.95	0.08	49,49,49,49	0

The following is a graphical depiction of the model fit to experimental electron density of all instances of the Ligand of Interest. In addition, ligands with molecular weight > 250 and outliers as shown on the geometry validation Tables will also be included. Each fit is shown from different orientation to approximate a three-dimensional view.

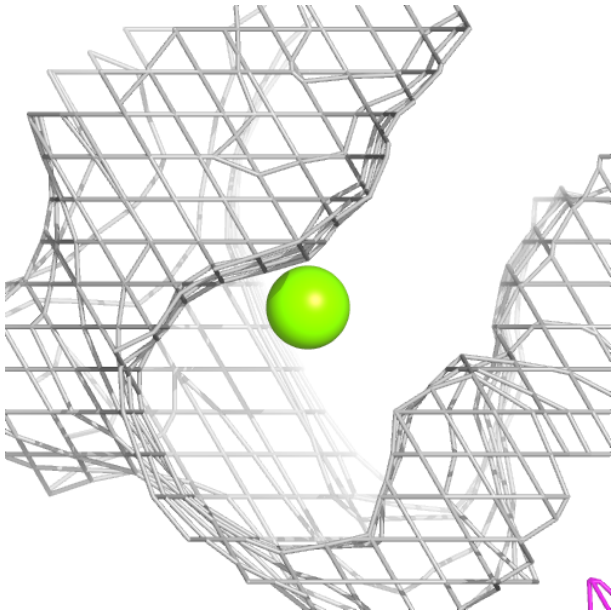
Electron density around FPP A 401:

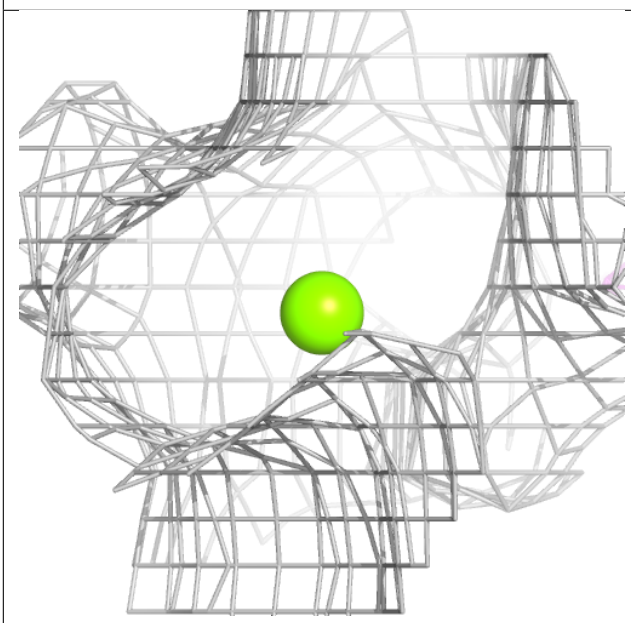
$2mF_o$-DF_c (at 0.7 rmsd) in gray
mF_o-DF_c (at 3 rmsd) in purple (negative) and green (positive)

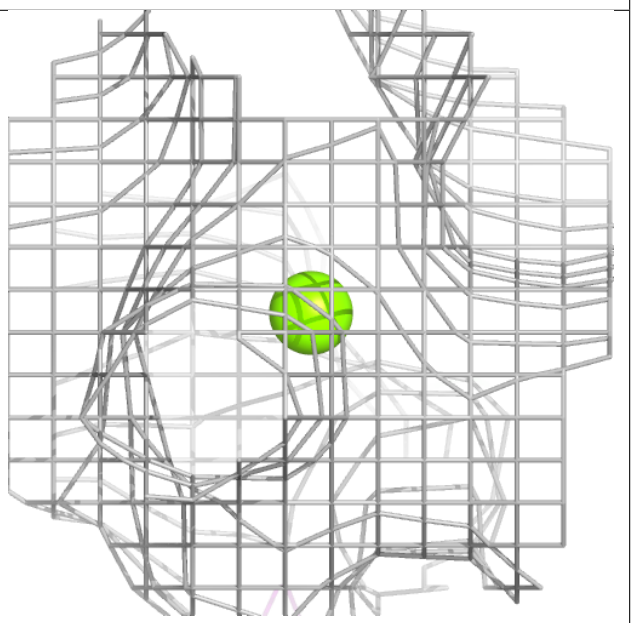


Electron density around MG A 402:

$2mF_o$-DF_c (at 0.7 rmsd) in gray
mF_o-DF_c (at 3 rmsd) in purple (negative) and green (positive)

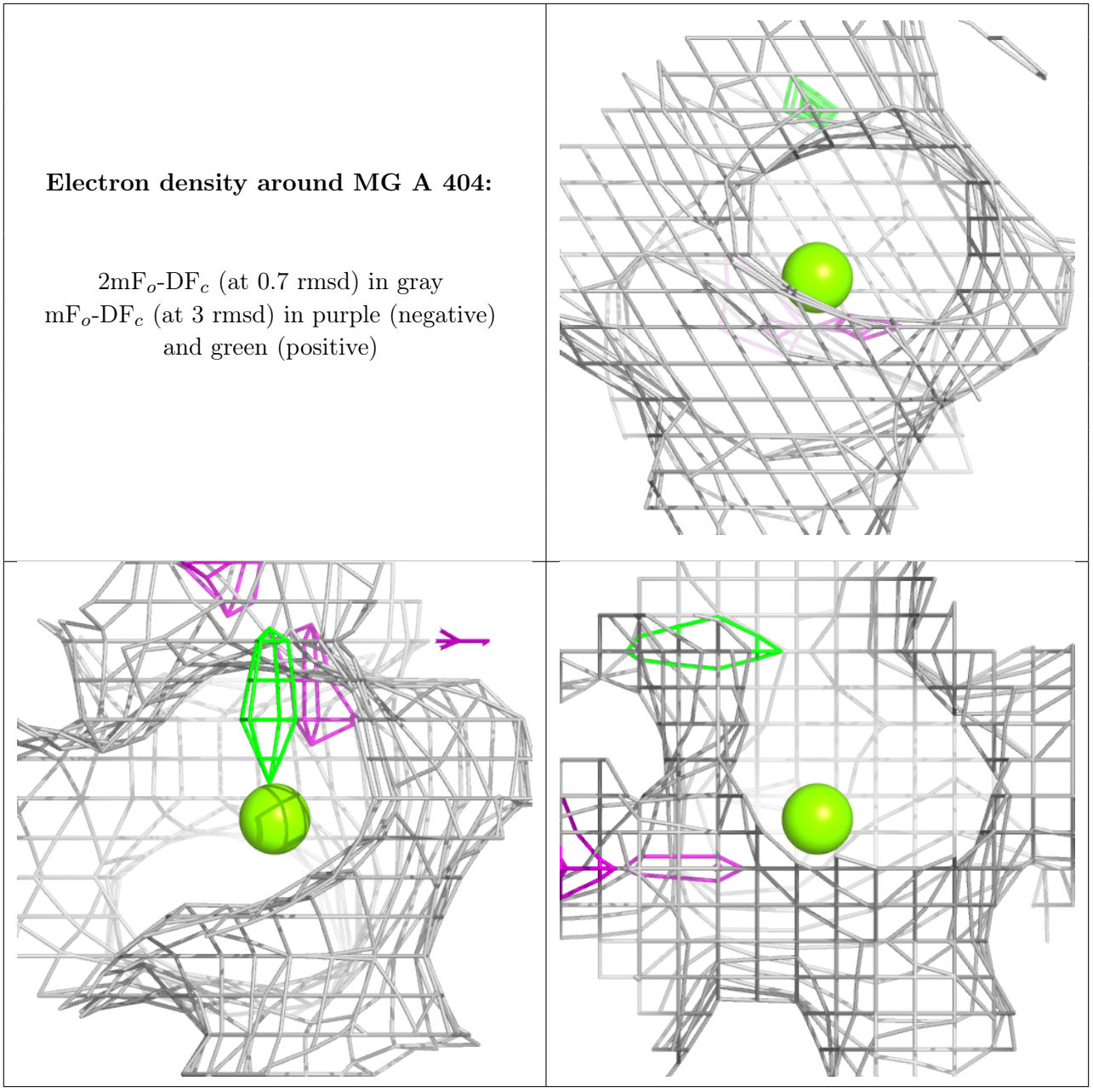






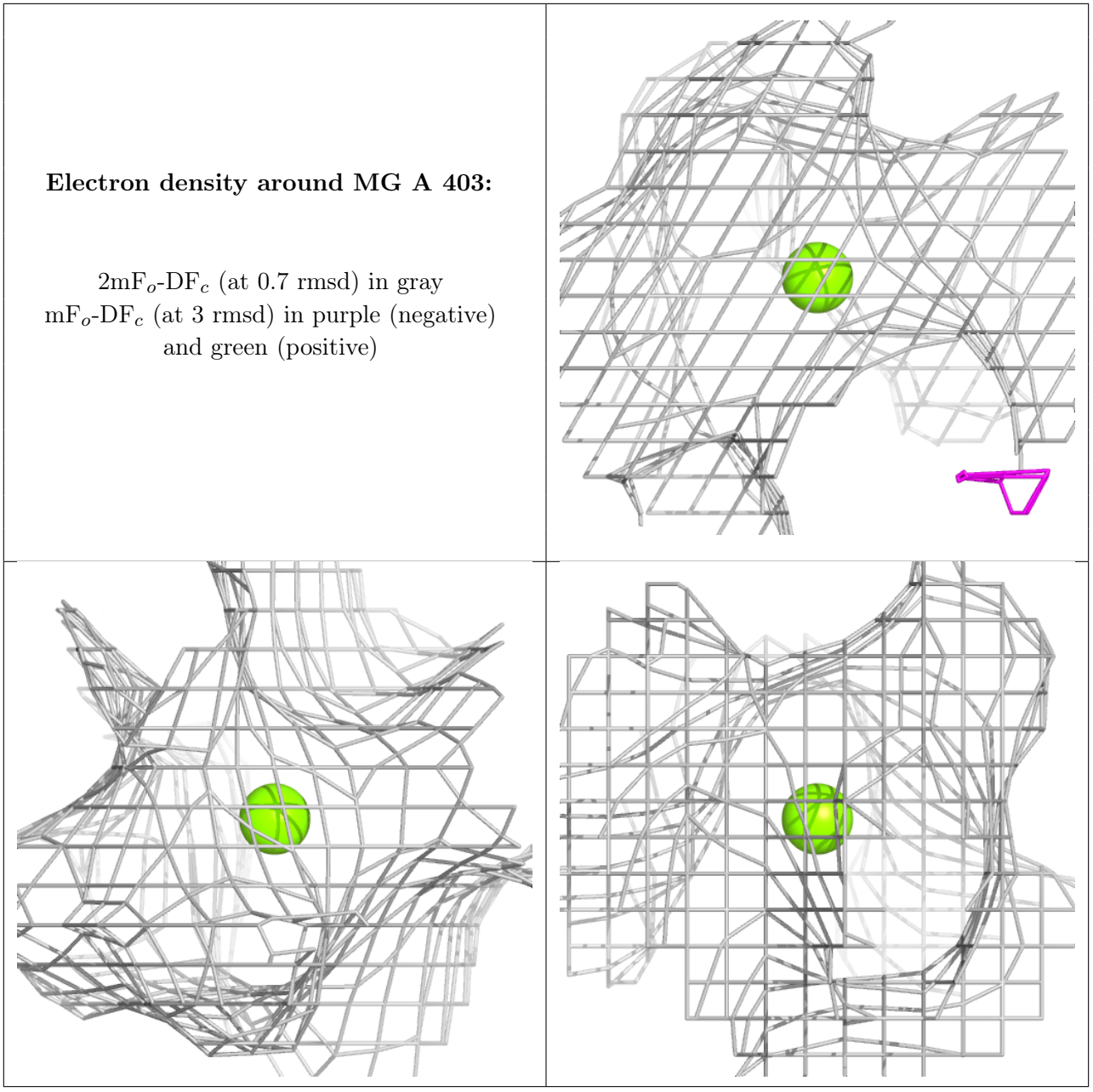
Electron density around MG A 404:

$2mF_o$-DF_c (at 0.7 rmsd) in gray
mF_o-DF_c (at 3 rmsd) in purple (negative) and green (positive)



Electron density around MG A 403:

$2mF_o$-DF_c (at 0.7 rmsd) in gray
mF_o-DF_c (at 3 rmsd) in purple (negative) and green (positive)



6.5 Other polymers

There are no such residues in this entry.